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Short Communication

Screening of bread wheat (*Triticum aestivum* L. em. Thell.) genotypes under heat stress environment

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Bread wheat (*Triticum aestivum* L. em. Thell.) alone accounts for about 34 per cent of the total food grain production and will continue to play a crucial role in the food security of the country. Breeding of heat stress tolerance forms an integral component of wheat breeding programmes at both national and international level. Thermo tolerance in wheat cultivars requires understanding of the physiological responses of wheat crop to heat stress, which will help in identifying traits, to be used as selection criteria. The present study was carried out to understand the effect on morpho-physiological traits under high temperature conditions and identification of tolerant genotypes.

Ten diverse genotypes of bread wheat and their resulting 45 F_1s and 45 F_2s were evaluated in *rabi* season at ARS, SKRAU, Durgapura, Jaipur in three replications under normal (E_1 - 20th November) and late (E_2 - 20th December) sown conditions using RBD. Each experimental plot consisted of 2 rows (for parents and F_1s) and 6 rows (for F_2s) of 3 m length with 30 x 10 cm spacing in both environments. Non-experimental rows were planted all around the experimental plot to avoid border effects. Recommended cultural practices were followed for raising the normal wheat crop. Observations were recorded on seven morpho-physiological characters (Table 1), in each entry and each replication in both sowing conditions. Heat susceptibility index (HSI) was calculated for grain yield and other attributes over high temperature stress and non-stress environment by using the formula as suggested by Fischer and Maurer [1]. HSI = [1-YD/YP]/D, where, YD = mean of the genotypes in stress environment, YP = mean of the genotypes under non-stress environment; D = 1-[mean YD of all genotypes/mean YP of all genotypes]. The HSI values were used to characterize the relative tolerance of genotypes based on minimization of yield losses compared to normal environmental conditions. The differences between genotypes for different characters were tested for significance by using standard techniques for analysis of variances.

The analysis of variance showed highly significant differences among genotypes of various characters in two environments indicating the influence of sowing condition on genotypes and traits. Further it was observed that all the characters responded to high temperature stress in different way in different genotypes. The mean of parents, F_1s and F_2s for different characters decreased under E_2 (late sown) environment in comparison to E_1 (normal sown) environment (Table 1). The results are in agreement with other reports [2, 3].

Parent UP 2611, HUW 567, HD 2859 and Raj 4058 for days to heading; HP 1863, Raj 4058 and HUW 567 for plant height; UP 2611, PBW 533 and JKW 8 for 1000-grain weight; JKW 8, HD 2611 and HP 1863 for

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grain weight per ear; UP 2611, HD 2859 and HP 1863 for biological yield per plant; HUW 567, Raj 4058 and HD 2859 for harvest index and UP 2611, HD 2859 and HP 1863 for grain yield per plant were least affected under late sown conditions (E_2). An overall appraisal indicated that UP 2611, HD 2859 were heat tolerant and HP 1863 were found to be good parents for grain yield per plant based on HSI (Table 1).

Among the F_1 crosses, JKW 8 x UP 2590, JKW 8 x HD 2859 and HD 2859 x PBW 509 for days to heading; JKW 8 x PBW 509, HP 1863 x WH 786 and HP 1863 x UP 2590 for plant height; HUW 567 x UP 2590, HP 1863 x JKW 8, WH 786 x JKW 8 and WH 786 x HUW 567 for 1000-grain weight; UP 2611 x UP 2590, WH 786 x HUW 567 and PBW 533 x HD 2859 for grain weight per ear; WH 786 x JKW 8, UP 2611 x HD 2859 and WH 786 x UP 2590 for biological yield per plant; JKW 8 x HD 2859, UP 2611 x PBW 533 and UP 2611 x PBW 509 for harvest index and WH 786 x UP 2590 for grain yield per plant were least affected under late sown conditions (E_2). In general, WH 786 x JKW 8, UP 2611 x HD 2859 and WH 786 x HUW 567 were found to be good F_1 crosses for grain yield per plant based on HSI (Table 2).

Among the F_2 crosses, HP 1863 x UP 2611, WH 786 x UP 2590 and UP 2611 x PBW 533; for days to heading; HUW 567 x UP 2590, HUW 567 x PBW 509 and Raj 4058 x PBW 509 for plant height; WH 786 x HUW 567, UP 2611 x HUW 567 and UP 2611 x PBW 509 for 1000-grain weight; WH 786 x PBW 533, WH 786 x PBW 509 and HUW 567 x PBW 509 for grain weight per ear; HUW 567 x PBW 509, WH 786 x JKW 8 and WH 786 x PBW 533 for biological yield per plant; HP 1863 x HD 2859, HP 1863 x UP 2590 and UP 2611 x PBW 533 for harvest index and HUW 533 x Raj 4058 x HD 2859 for grain yield per plant were least affected under late sown condition (E_2). In general, the crosses HUW 567 x PBW 509 and WH 786 x JKW 8 were found to be good F_2 crosses for grain yield per plant based on HSI (Table 2).

In order to determine relative tolerance, the heat susceptibility index was estimated for various genotypes. Based upon the value and direction of desirability, ranking was done for different genotypes as highly heat tolerant (HSI < 0.50), heat tolerant (HSI: 0.51-0.75), moderately heat tolerant (HSI: 0.76 – 1.00) and heat susceptible (HSI > 1.00). An overall appraisal

Table 1. Heat susceptibility indices of parents and mean of parents, their F_1 s and F_2 s for various characters in normal (E_1) and late (E_2) sown condition in bread wheat

Parents		Days to heading	Plant height (cm)	1000-grain weight (g)	Grain weight / ear (g)	Biological yield / plant (g)	Harvest index (%)	Grain yield/ plant (g)
HP 1863 (P_1)		0.93	–1.22	0.78	0.57	0.64	1.51	0.75
WH 786 (P_2)		1.40	2.13	1.35	0.89	1.13	1.30	1.13
UP 2611 (P_3)		0.52	1.43	0.46	0.56	0.21	1.27	0.38
HUW 567 (P_4)		0.52	0.03	1.11	1.13	0.95	0.04	0.83
Raj 4058 (P_5)		0.72	–0.78	1.12	1.46	1.53	0.11	1.35
PBW 533 (P_6)		1.26	1.62	0.65	1.50	1.71	1.10	1.60
JKW 8 (P_7)		1.10	1.86	0.75	0.52	1.13	1.40	1.15
UP 2590 (P_8)		1.43	1.09	1.75	1.39	1.35	1.27	1.32
HD 2859 (P_9)		0.70	0.91	0.78	0.52	0.55	0.20	0.50
PBW 509 (P_{10})		1.24	1.84	1.12	1.27	0.76	1.78	0.89
D-value		0.08	0.09	0.20	0.31	0.27	0.05	0.26
Mean								
Parents	E_1	80.60	75.75	33.67	14.28	33.59	42.52	1.84
	E_2	74.50	68.67	26.86	9.89	24.52	40.58	1.36
F_1 crosses	E^1	80.51	77.42	35.26	17.63	42.66	41.46	2.00
	E_2	74.44	65.55	28.97	10.07	25.65	39.47	1.42
F_2 crosses	E_1	79.44	75.08	33.09	15.79	39.16	40.43	1.83
	E_2	71.69	82.23	23.84	7.67	19.93	38.63	1.12

Table 2. Heat susceptibility indices of F_1 and F_2 crosses for various characters in bread wheat

Crosses	F_1							F_2						
	Days to heading	Plant height (cm)	1000-grain weight (g)	Grain weight/ ear (g)	Biological yield / plant (g)	Harvest index (%)	Grain yield/ plant (g)	Days to heading	Plant height (cm)	1000-grain weight (g)	Grain weight/ ear (g)	Biological yield/ plant (g)	Harvest index (%)	Grain yield / plant (g)
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
P_1 X P_2	0.85	-0.43	0.47	0.84	0.79	1.52	0.86	1.15	1.41	1.55	1.21	1.20	1.55	1.20
P_1 X P_3	1.02	0.13	0.74	1.07	1.12	1.00	1.10	0.54	1.42	1.48	1.26	1.09	0.64	1.07
P_1 X P_4	1.05	0.41	0.73	1.10	0.73	1.95	0.83	0.69	-0.09	1.20	0.83	0.98	1.30	1.00
P_1 X P_5	0.96	1.14	1.01	1.01	0.78	1.46	0.83	0.77	1.25	0.89	1.32	1.12	1.18	1.12
P_1 X P_6	0.34	0.85	0.61	0.99	1.07	0.16	1.01	0.68	0.58	0.92	0.79	0.97	1.08	0.98
P_1 X P_7	0.98	1.44	-0.16	0.69	1.09	0.44	1.04	0.96	1.21	0.84	1.16	1.10	0.66	1.08
P_1 X P_8	1.85	-0.07	1.37	1.51	1.08	0.90	1.06	1.84	1.07	1.18	1.00	1.09	0.18	1.05
P_1 X P_9	1.25	0.63	0.42	0.50	1.06	0.53	1.02	1.51	-0.02	1.08	0.86	1.03	-0.01	0.99
P_1 X P_{10}	0.82	1.66	0.45	1.07	0.90	0.96	0.91	0.92	1.31	0.82	0.83	0.97	2.60	1.05
P_2 X P_3	0.53	0.98	0.09	0.76	0.98	2.04	1.06	1.06	1.20	0.92	1.30	1.15	1.19	1.15
P_2 X P_4	1.15	0.74	0.24	0.37	0.56	1.23	0.64	0.94	1.48	0.19	0.79	0.89	0.48	0.88
P_2 X P_5	1.41	1.56	0.58	0.70	0.86	0.29	0.83	1.05	0.32	1.02	0.56	0.79	1.25	0.83
P_2 X P_6	1.26	0.58	0.80	1.60	1.22	1.59	1.23	1.08	2.05	0.76	0.07	0.55	1.93	0.65
P_2 X P_7	1.70	0.33	0.05	0.70	0.41	0.44	0.41	0.76	1.18	0.68	0.67	0.49	1.66	0.58
P_2 X P_8	1.26	0.79	0.42	0.88	0.62	1.64	0.72	0.54	1.77	1.37	1.58	0.92	2.01	0.98
P_2 X P_9	1.06	-0.04	0.75	0.77	0.75	1.25	0.80	0.91	0.70	1.26	1.34	1.22	0.95	1.20
P_2 X P_{10}	1.15	1.58	1.38	1.16	0.94	0.21	0.89	1.48	1.06	0.75	0.51	0.84	0.42	0.83
P_3 X P_4	0.98	-0.07	1.61	0.71	0.77	0.44	0.74	0.87	1.09	0.19	0.72	0.94	1.59	0.98
P_3 X P_5	0.96	1.55	1.15	1.10	1.09	1.74	1.13	0.91	0.74	0.54	0.87	1.16	0.49	1.12
P_3 X P_6	1.11	1.52	0.79	1.18	0.86	0.14	0.81	0.57	1.18	1.13	1.21	0.83	0.20	0.81
P_3 X P_7	1.28	1.42	0.68	0.63	0.83	0.67	0.83	0.80	1.25	0.92	1.05	0.94	0.35	0.91

(Table 2 Cont..)

Crosses	F1							F2						
	Days to heading	Plant height (cm)	1000-grain weight (g)	Grain weight/ ear (g)	Biological yield / plant (g)	Harvest index (%)	Grain yield/ plant (g)	Days to heading	Plant height (cm)	1000-grain weight (g)	Grain weight/ ear (g)	Biological yield/ plant (g)	Harvest index (%)	Grain yield / plant (g)
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
P_3 X P_8	0.81	1.49	0.41	0.22	0.79	0.66	0.78	1.14	2.01	1.37	0.94	1.15	0.57	1.12
P_3 X P_9	0.87	1.12	1.36	0.72	0.60	0.70	0.62	1.26	0.98	0.96	1.40	1.26	0.54	1.22
P_3 X P_{10}	0.97	1.56	1.05	1.63	1.48	0.14	1.39	1.58	2.14	0.22	0.70	0.63	0.34	0.63
P_4 X P_5	0.72	0.26	0.78	0.89	1.06	1.99	1.11	1.15	2.36	1.28	1.27	1.13	0.97	1.11
P_4 X P_6	1.36	1.47	1.13	1.16	1.23	0.30	1.17	1.20	1.77	0.66	0.89	0.91	0.46	0.89
P_4 X P_7	1.25	0.66	0.97	0.44	0.68	1.59	0.78	1.31	0.36	1.10	1.35	1.20	1.63	1.20
P_4 X P_8	1.05	0.35	-0.23	0.51	0.81	0.23	0.77	1.01	-0.53	1.07	1.09	0.98	0.59	0.96
P_4 X P_9	1.44	-0.02	0.74	1.16	1.05	1.88	1.09	0.92	-0.02	0.98	1.13	1.08	0.21	1.05
P_4 X P_{10}	1.18	0.99	1.50	1.54	1.33	2.07	1.34	1.02	-0.33	0.85	0.54	0.48	1.13	0.53
P_5 X P_6	0.84	1.51	1.38	0.87	1.20	0.47	1.14	1.01	0.76	1.42	1.08	1.32	0.66	1.28
P_5 X P_7	0.85	1.44	0.69	0.94	0.74	2.07	0.83	0.92	0.91	1.26	1.32	1.21	1.41	1.20
P_5 X P_8	0.81	1.72	1.81	0.94	1.11	0.38	1.04	1.00	1.44	1.11	1.34	1.24	0.97	1.22
P_5 X P_9	0.97	1.55	2.18	1.16	1.31	0.86	1.27	0.90	0.98	1.22	1.05	0.76	1.01	0.78
P_5 X P_{10}	1.02	0.07	1.59	1.08	1.05	1.70	1.08	0.84	-0.43	1.05	0.86	0.84	1.04	0.85
P_6 X P_7	0.87	1.24	1.63	1.13	1.19	0.66	1.15	0.91	1.65	1.21	1.10	1.04	0.69	1.02
P_6 X P_8	0.97	0.95	1.68	0.76	0.91	1.64	0.97	1.01	1.40	0.96	1.02	0.98	0.43	0.95
P_6 X P_9	0.97	1.43	0.93	0.38	0.71	1.01	0.74	1.02	0.80	0.91	0.56	1.14	0.67	1.13
P_6 X P_{10}	0.81	1.66	1.11	0.87	1.25	0.69	1.20	1.15	0.72	1.17	1.47	1.33	1.35	1.31
P_7 X P_8	-0.18	1.51	1.62	1.64	1.55	0.84	1.48	1.18	0.34	1.18	1.06	0.88	2.33	0.96
P_7 X P_9	0.50	0.82	1.92	1.25	1.20	-0.16	1.11	1.02	0.55	0.72	0.98	0.74	1.41	0.79
P_7 X P_{10}	1.41	-1.08	0.52	1.09	1.22	0.37	1.15	0.64	0.61	1.17	0.55	0.97	1.34	1.00
P_8 X P_9	0.98	2.20	1.65	1.28	1.30	1.53	1.30	0.63	0.58	1.26	0.61	0.76	1.07	0.79
P_8 X P_{10}	0.67	0.90	1.33	1.33	1.06	1.32	1.08	0.90	1.35	0.46	0.60	0.69	1.54	0.75
P_9 X P_{10}	0.50	2.10	1.93	1.40	1.04	1.12	1.04	0.94	1.03	1.15	1.04	1.12	0.78	1.11
D-value	0.08	0.15	0.18	0.43	0.40	0.05	0.29	0.10	0.17	0.28	0.51	0.49	0.04	0.39

revealed the parent UP 2611, HD 2859 and HP 1863, the F_1 crosses WH 786 x JKW 8, UP 2611 x HD 2859 and WH 786 x HUW 567 and the F_2 crosses WH 786 x JKW 8, HUW 567 x PBW 509 and UP 2611 x PBW 509 for grain yield per plant were least affected under late sown conditions. High grain yield of a genotype under late sown condition indicated the presence of genes for heat tolerance. Comparison across the generations indicated that the cross WH 786 x JKW 8 emerged as highly heat tolerant in F_1 and heat tolerant in F_2 for grain yield per plant.

Considering D-value i.e. heat stress intensity it was revealed that days to heading, plant height and harvest index were less affected by late sown condition, while grain weight per ear, biological yield per plant and grain yield per plant highly suffered under E_2 environment. This clearly indicated that grain yield depends on biological yield and grain weight per ear. Similar results were also reported by other researchers [3, 4]. Blum *et al.* [5] emphasized that selection for high biomass yield should bring about positive improvement in grain yield and 1000-grain weight. Thus, biomass yield could be improved by plant height. In the present investigation plant height significantly contributed towards biomass because less reduction in plant height (D = 0.09, 0.15 and 0.17 for parents, F_1s and F_2s, respectively) in E_2 environment. Thus, selection for biomass yield is one of the most important ways to improve the productivity under late sown conditions.

Most of the traits were adversely affected under late sown conditions. It was therefore, essential to develop a scale for sorting parents and crosses for their relative tolerance to high temperature. In the present study that based on HSI (i.e. below 1), the parental genotype UP 2611, HD 2859 and HP 1863, the F_1 crosses WH 786 x JKW 8, UP 2611 x HD 2859 and WH 786 x HUW 567 and the F_2 crosses WH 786 x JKW 8, HUW 567 x PBW 509 and UP 2611 x PBW 509 for grain yield per plant were least affected under late sown conditions. These parents and crosses should be further exploited for improvement of grain yield under late sown conditions. The HSI could be taken as important criteria for breeding wheat genotypes suitable for late sown conditions.

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